Experience with large LST systems

Kwong Lau
University of Houston
On Behalf of
The SCARF and SMC Collaborations
January 25, 2003

Outline

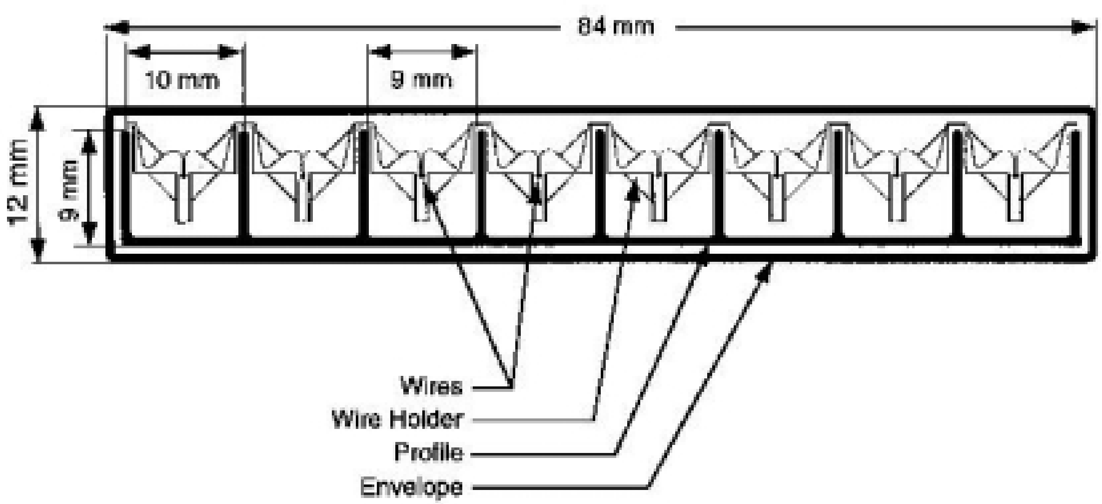
- General Introduction
- Global consumption of LSTs
- SCARF experience
  - Major Improvements made at SCARF
  - Examples of QC done at SCARF
  - Achieved performance
  - Plateaus
  - Operation issues
- SMC experience
  - Rate limitation
  - HV feedback loop
- Conclusions

General Introduction

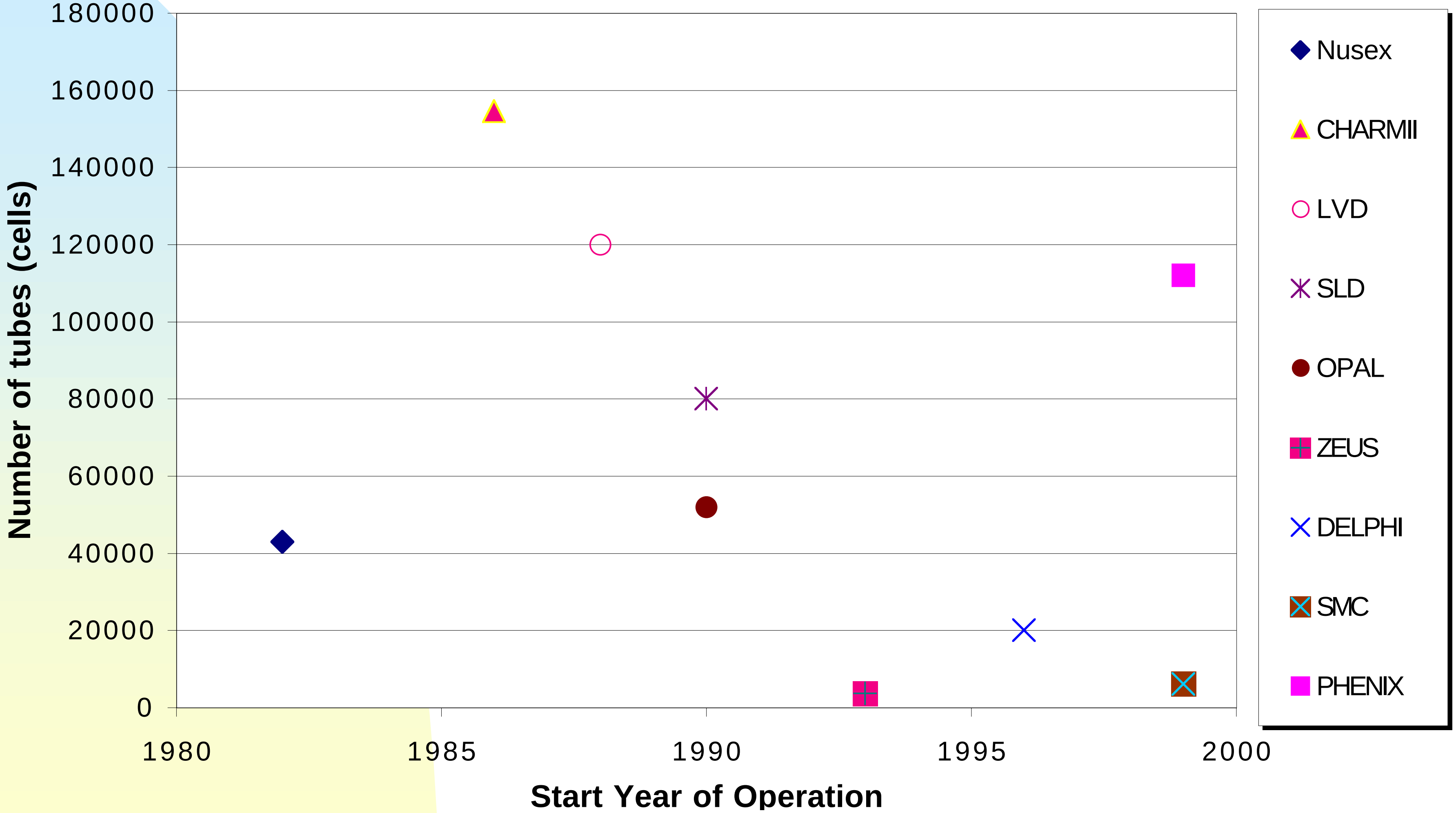
- The Limited streamer (self-quenching) mode is present in most wire chambers with thick wire (>50 micron) operated at a high voltage in a heavy quenching gas. The LSM is characterized by large & relatively constant signals
- The “Iarocci” LST package includes extruded PVC chamber structure and 3-sided graphite coated cathode allowing both anode and cathode readout from top (open side) regardless of cathode resistivity
- One can also read from the bottom side as well if the cathode is resistive (graphite coating resistance within some range)
- Large PST systems have been deployed with varying levels of success
- PST was clouded by suspicion and mystery due to the high short-term and long-term failure rates at the beginning
- Some observations and field results of SCARF-produced LSTs lifted some of the mysteries
- LST should be considered as a reliable (as reliable as a typical wire chamber) technology for appropriate applications (low rate)

Iarocci-style LSTs

- Cathodes are 3-sided carbon-coated profiles of 9 mmx9 mm (active area) square cells with 100 micron silver-plated Be-Cu anode wire
- Painted profiles are inserted in PVC sheaths and sealed by endplugs. HV distribution is done by a PC board inside. Anode signals are ORed in the PCB
- Gas inlet and outlet are part of the endplug.
- Signals are pickuped by external strips. Granularity of readout is configured by segmentation of readout strips.

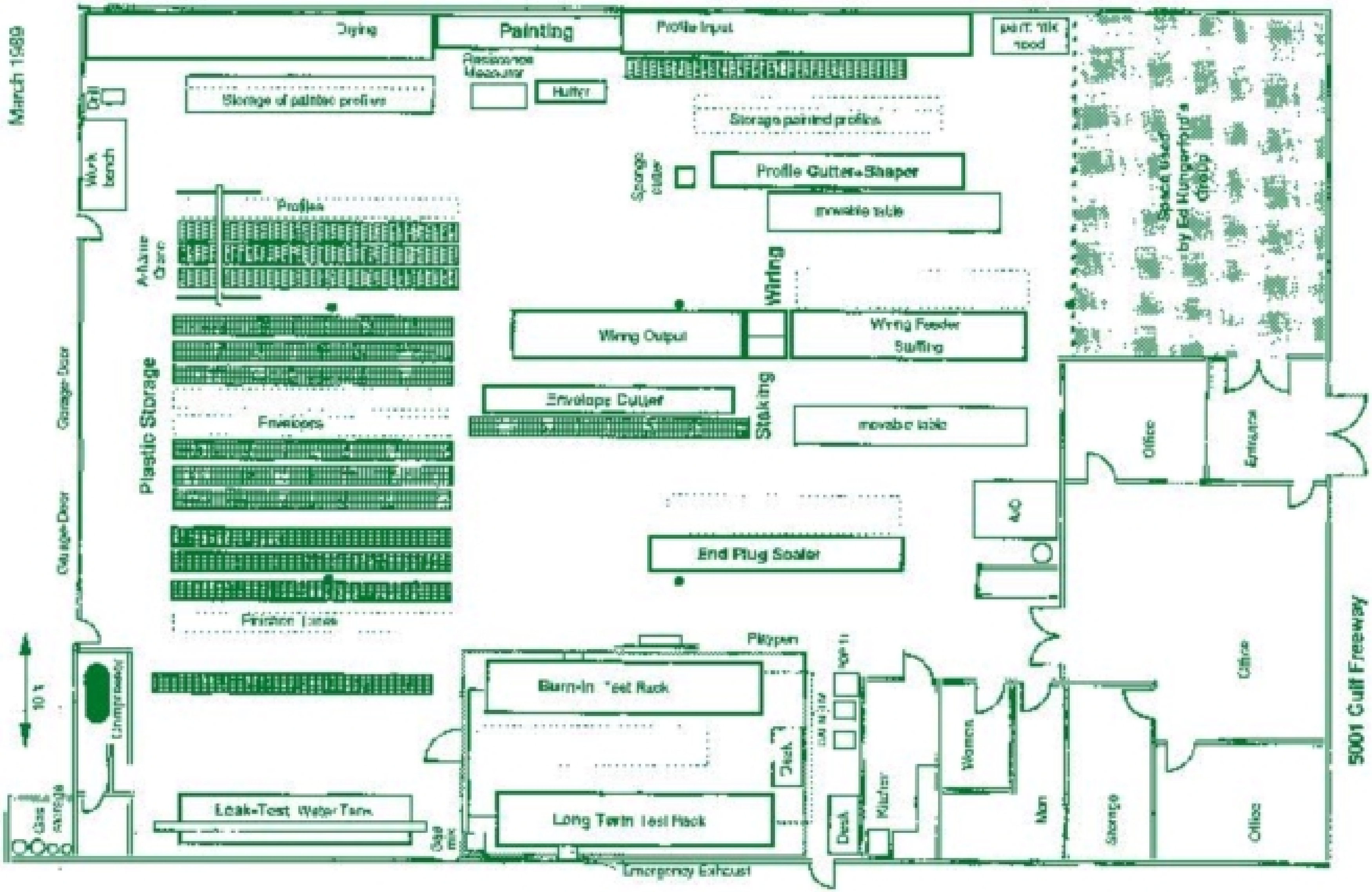


Global Consumption of LSTs

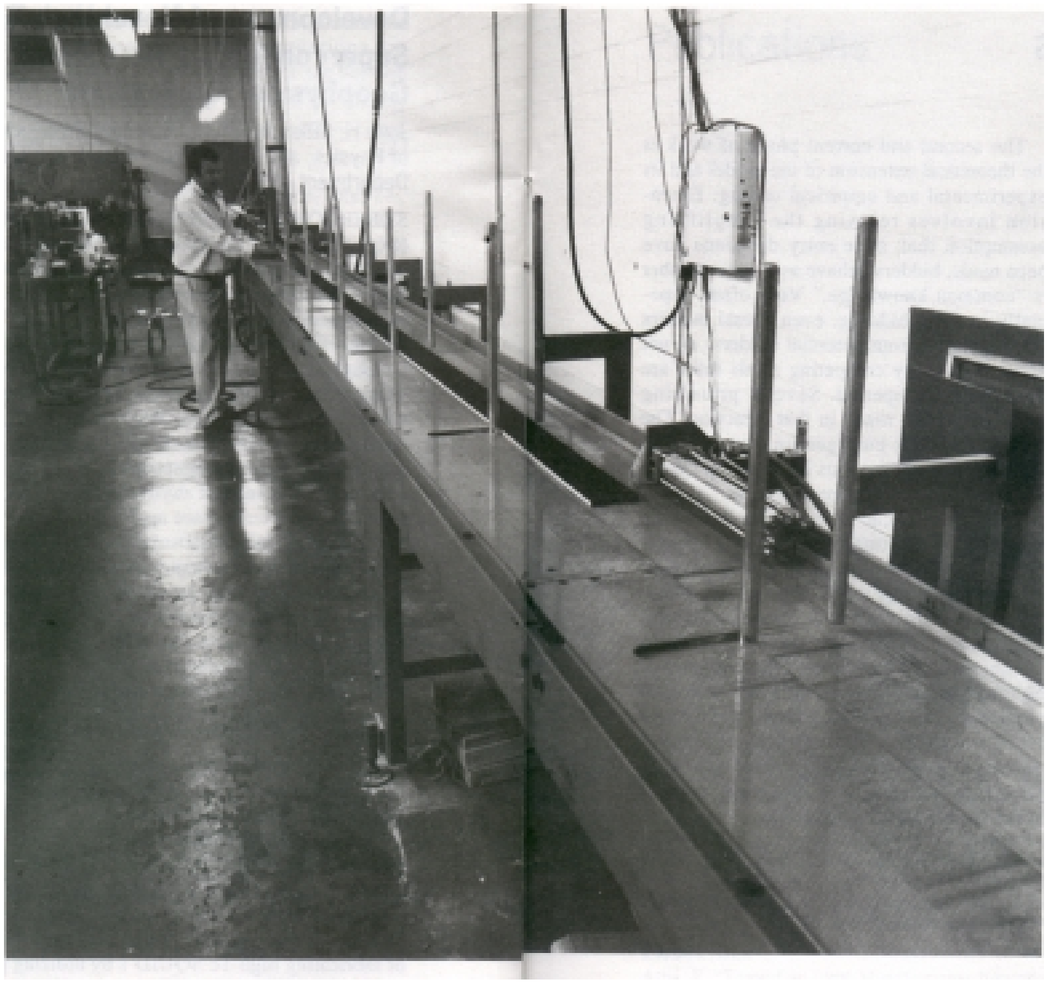


SCARF

- Funded by the State of Texas ARTP program to produce 400,000 6.3-meter LSTs for LVD at Gran Sasso. Extruded PVC parts were supplied by LVD collaboration, and full assembly work was done at SCARF.
- Facility was a 8000 sq ft warehouse located at U. of Houston, and was operated by a collaboration of HEP physicists from UH and NU with visitors from other institutions (MIT, Brown, Indiana, IHEP, ..)
- Participants included: Roy Weinstein, Eb von Goeler, Kwong Lau, Jorg Pyrlik, Jorge Moromisato, Dale Hungerford, Drew Parks, Hans Flick, Grant Mo, David Sanders, Jay Liu, I. Pless, Pei-Ruo Shen, Xiu-Zhen Yu
- Main contributions
  - Applied industry-style QC to all aspects of the production, and imposed tighter criteria on testing of products
  - Produced a large number of high quality chambers for LVD (20,000 8-cell chambers) in an industrial environment
  - A vigorous R&D program was pursued in parallel to understand the performance of the chambers
  - Produced special LSTs for high rate (SMC) and high-precision (CSC) applications

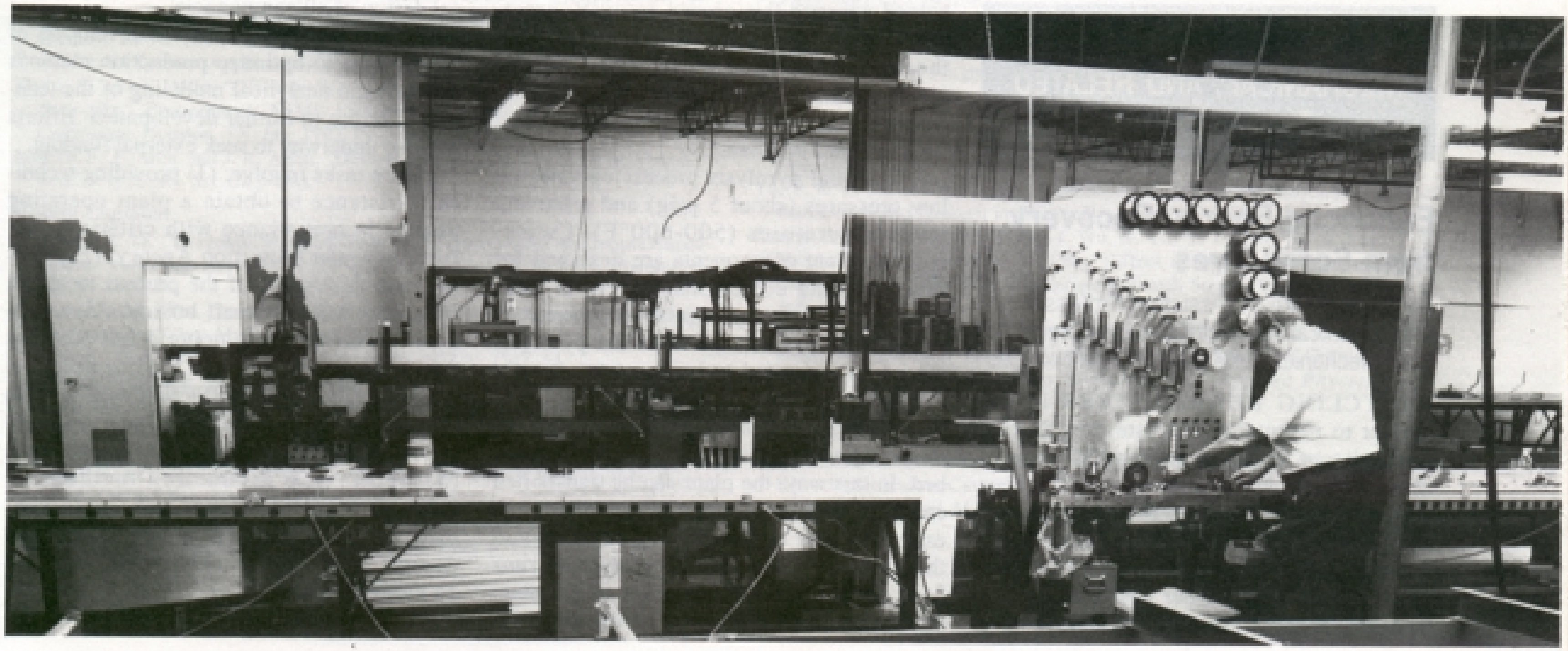

March 1989
Drying
Painting
Profile Input
Resistance Measurer
Huffer
Storage of painted profiles
Storage painted profiles
Work bench
Profile Cutter+Shaper
movable table
Profiles
Wiring
Wiring Output
Wiring Feeder
Stuffing
Plastic Storage
Envelope Cutter
Staking
movable table
Envelopes
Office
Entrance
End Plug Sealer
Finished Tubes
Playpen
Burn-In Test Rack
Leak-Test Water Tank
Long Term Test Rack
Emergency Exhaust
Office
Storage
Office
5001 Gulf Freeway
Garage Door

- Dale Hungerford working on the paint machine



- J. Pyrlik working on one of the cutting machines

R. Weinstein working on the wiring machine



ANNUAL REPORT 1991–92 25

Specific improvements at SCARF

- Used multiple graphite coating to reduce residual “bald spots” in cathode which are considered the major culprit of LSTs
- Raised the burn-in voltage from 5.1 kV normally done to 5.3 kV in standard gas with lower current limits; the minimum plateau for SCARF chamber is 400 V
- Paid diligent attention to gas-tightness of chambers
- Measured plateaus of 35 early production-line chambers (D. Hungerford et al., NIM)
- Did a long-term test of a random sample of 160 production line chambers for about 400 days (K.Lau et al., NIM)
- Studied effects of nitrogen in gas mixture (K.Lau et al., NIM letter)

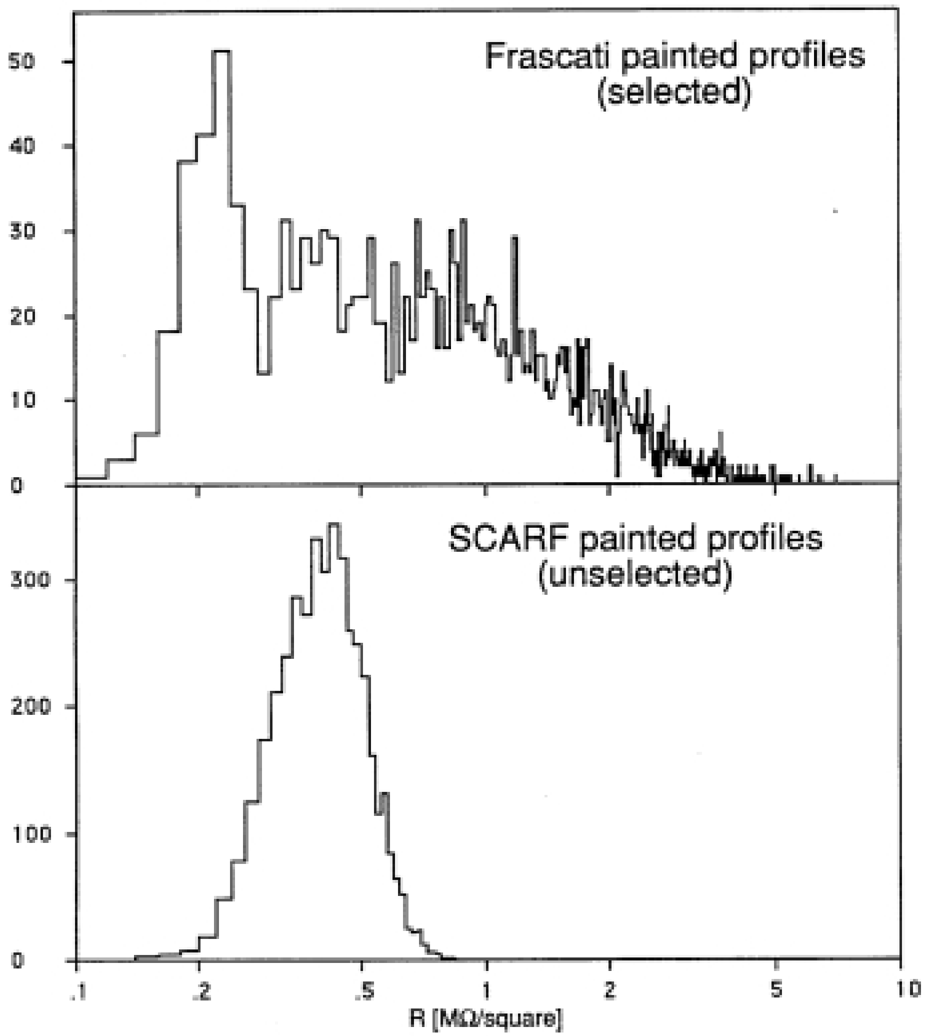
Examples of QC in painting & testing

- All mechanical vibrations of painting machine were reduced to minimum (no more streaks in painting) in initial shake-down
- Only use proven supplies
  - Graphite paint DAG 305 from Holland
  - Natural sponge from Spondex in France
- Chambers are moved by movable tables
- Use heat-seal
- Vigorous leak test
  - Vacuum chamber before flushing
  - Use Viton O-rings instead of Nylon washers for gas seal
- Keep good record of each chamber (resistance profile, burn-in record)

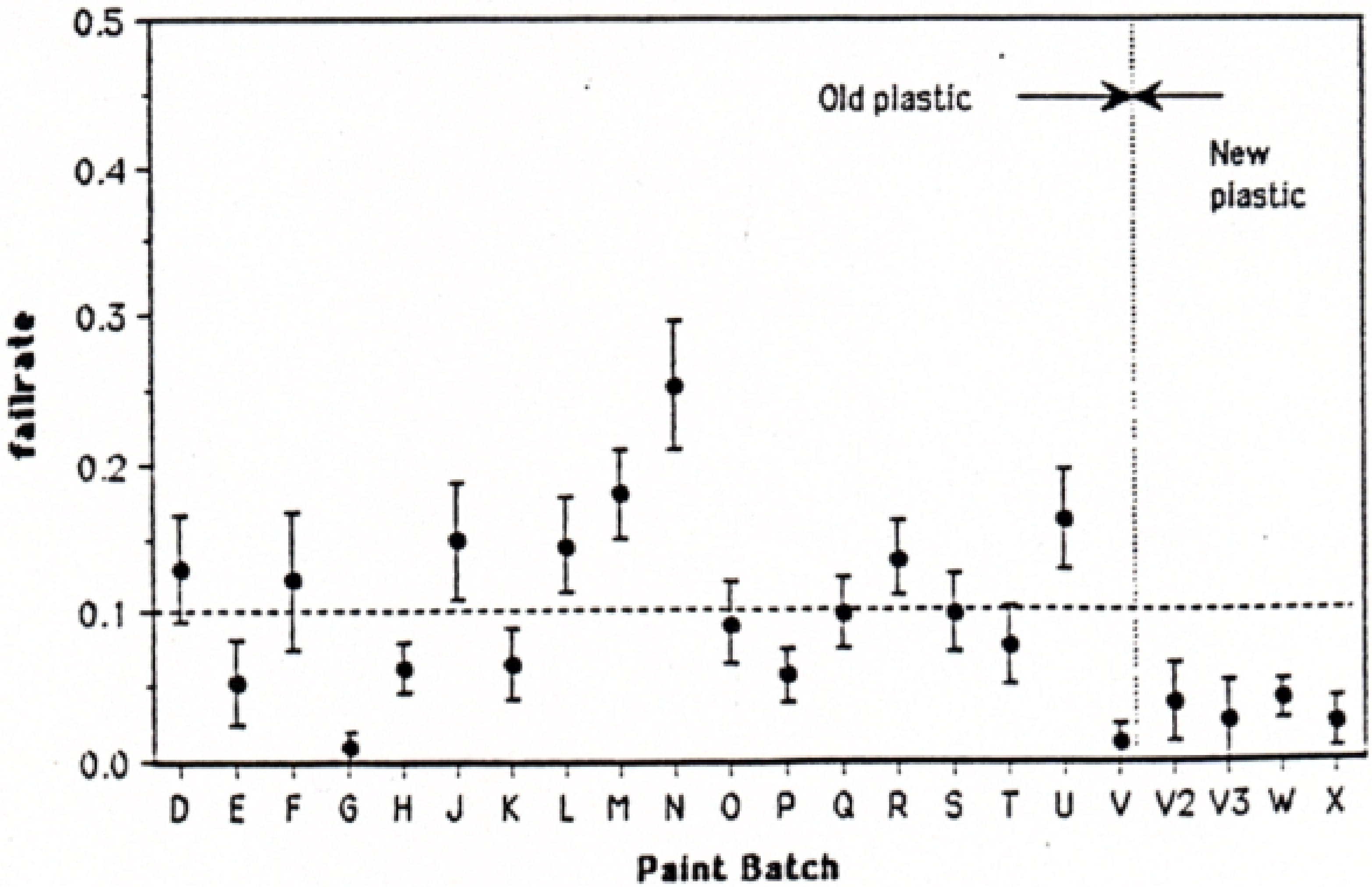
Achieved results

- 10% loss in painting, mostly due to start-stop and resistivity requirement
- 10% loss in burn-in, mostly due to flaws in production
- Re-burnin loss after moving chambers ranges from 0.4% to 10%, depending on experience of personnel performing the re-conditioning
- Perhaps some infant mortality, ranging from 3.5% in the first week (SCARF long-term test) to 10% in high-rate environment
- 0.5% to 1.5% long-term loss per year for 4-m chambers after the first year

Effect of multiple painting



Burn-in losses by paint batch



Plateau & singles rate studies

- The plateaus of the first 35 production-line chambers were measured in the standard and non-flammable gases.
- All measurements done with a typical deadline of 1 μs to suppress after-pulses
- Knee and breakaway are determined by straight-line fits
- Knee voltage is highly reproducible, independent of gas mixture
- Breakaway is probably due to run-away after-pulses, determined by gas or chamber defect whichever is lower; a broad distribution was observed
  - Standard gas can be up to 6000 V
  - Minimum plateau determined by burn-in voltage
  - SCARF upped the burn-in voltage from typical 5.1 to 5.3 kV without increase in burn-in failure rate
- Minimum SCARF chamber plateau is 400 V
- Chamber singles rate agrees cosmic ray and ambient radioactivity

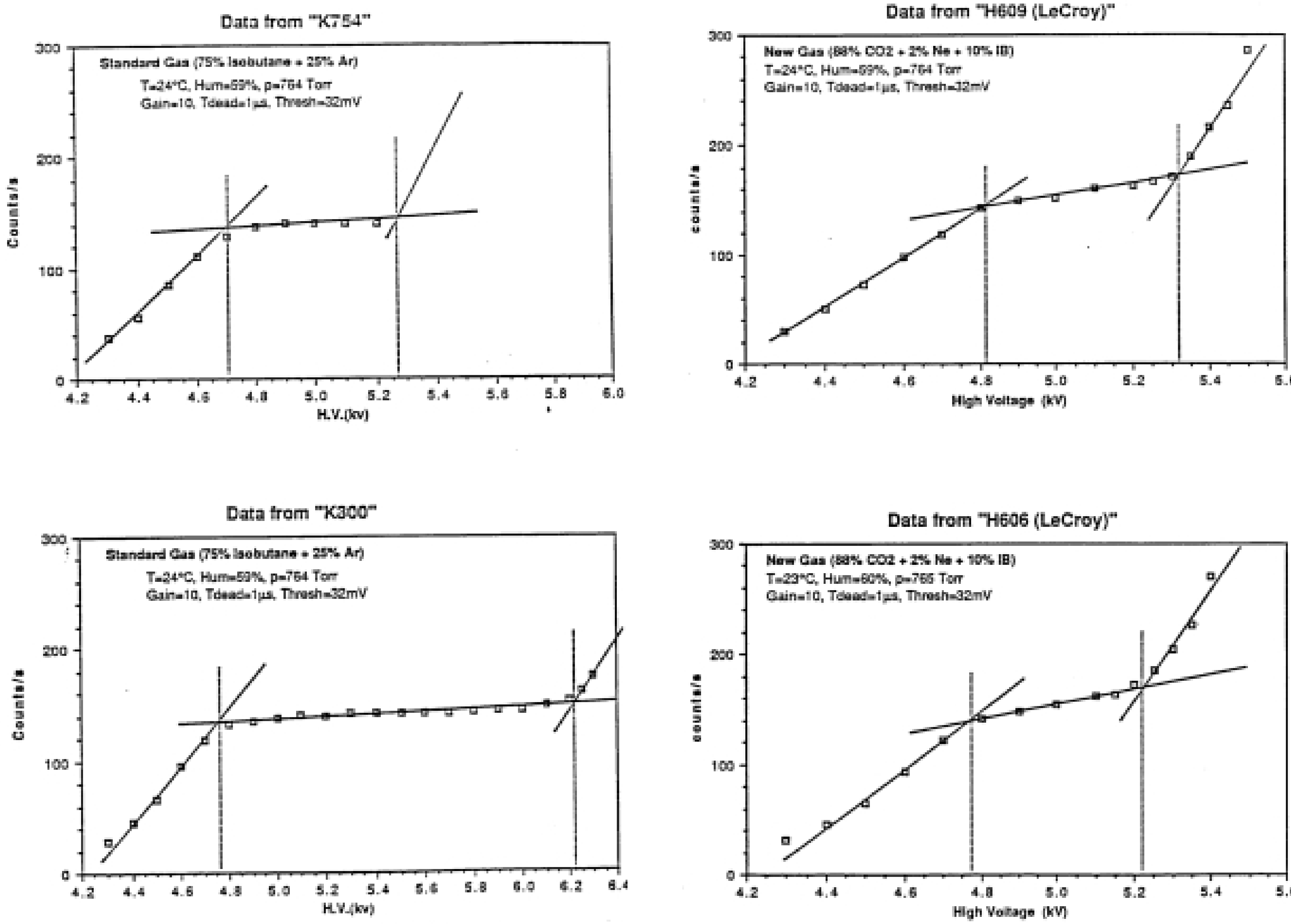
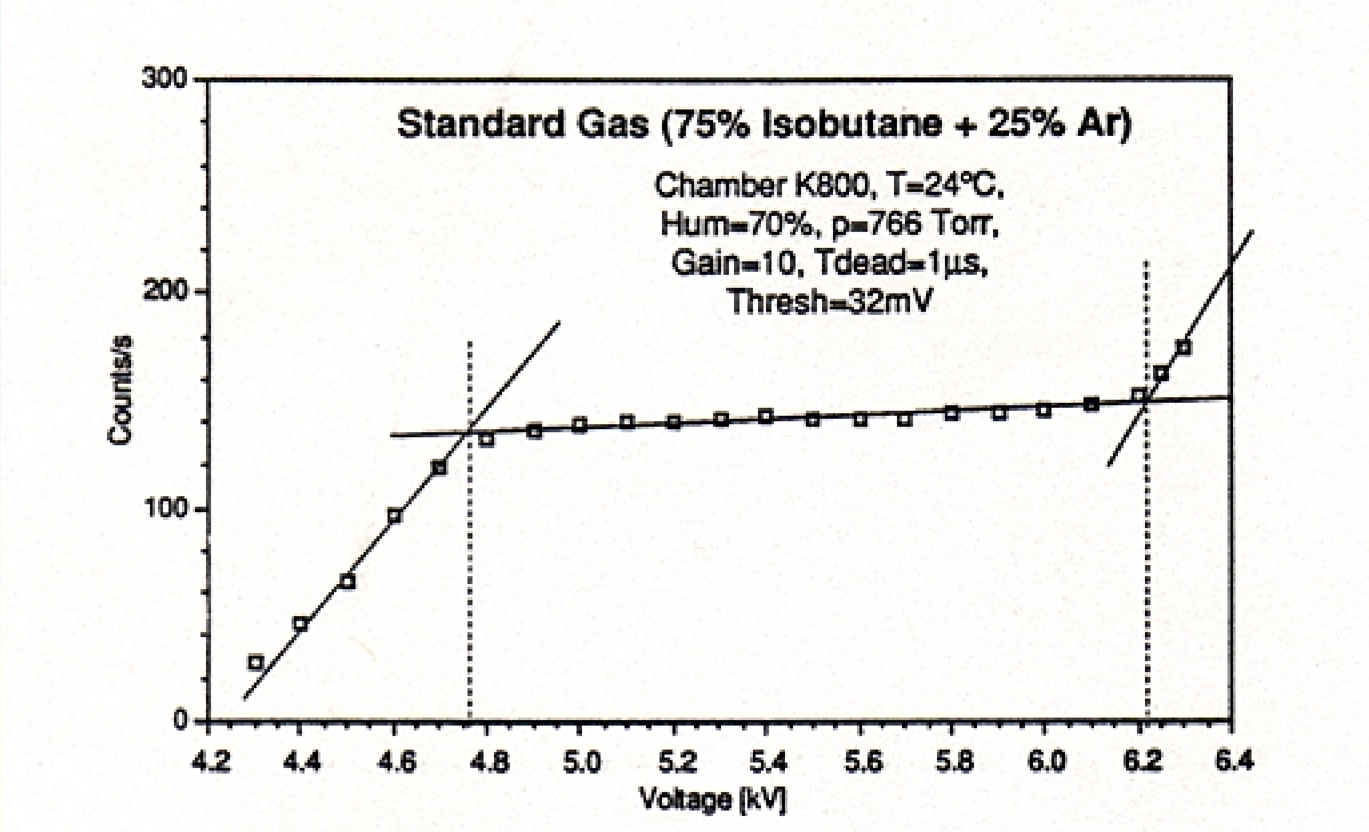


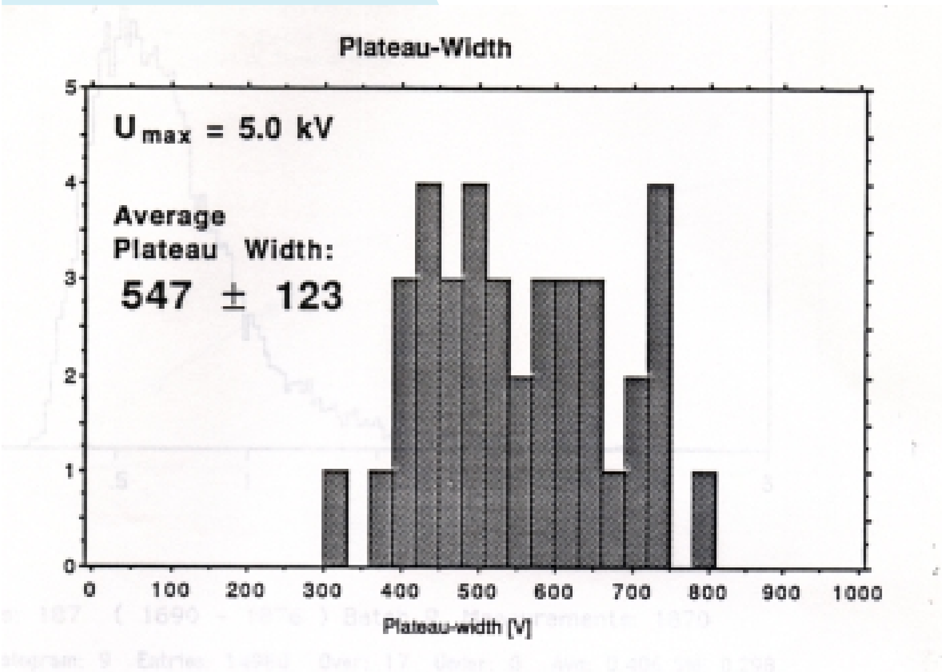
FIG. 5 PLATEAUS OF SCARF CHAMBERS

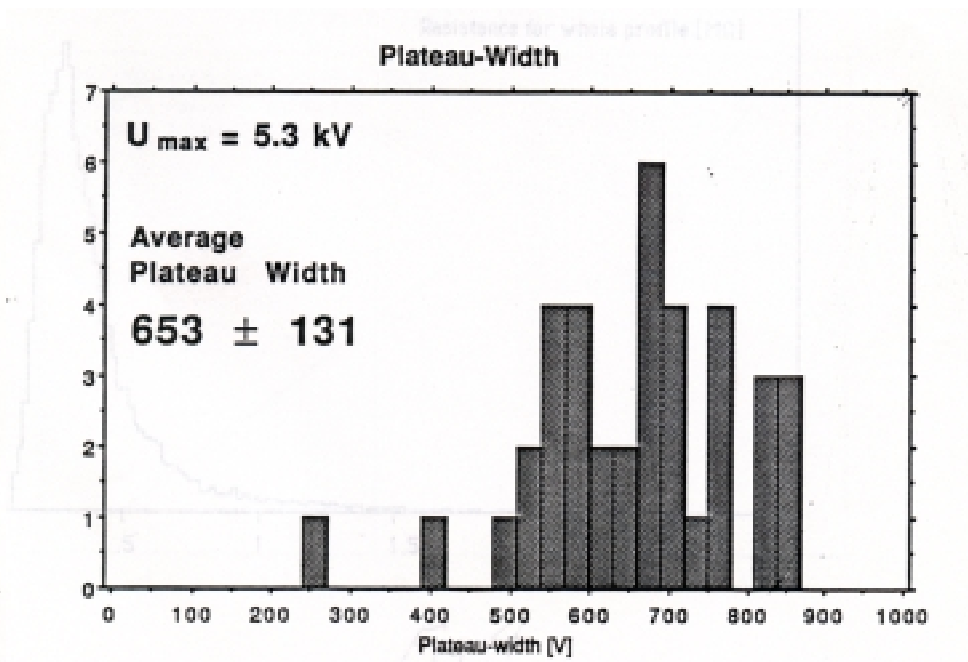
Longest plateau in standard gas (1400 V)



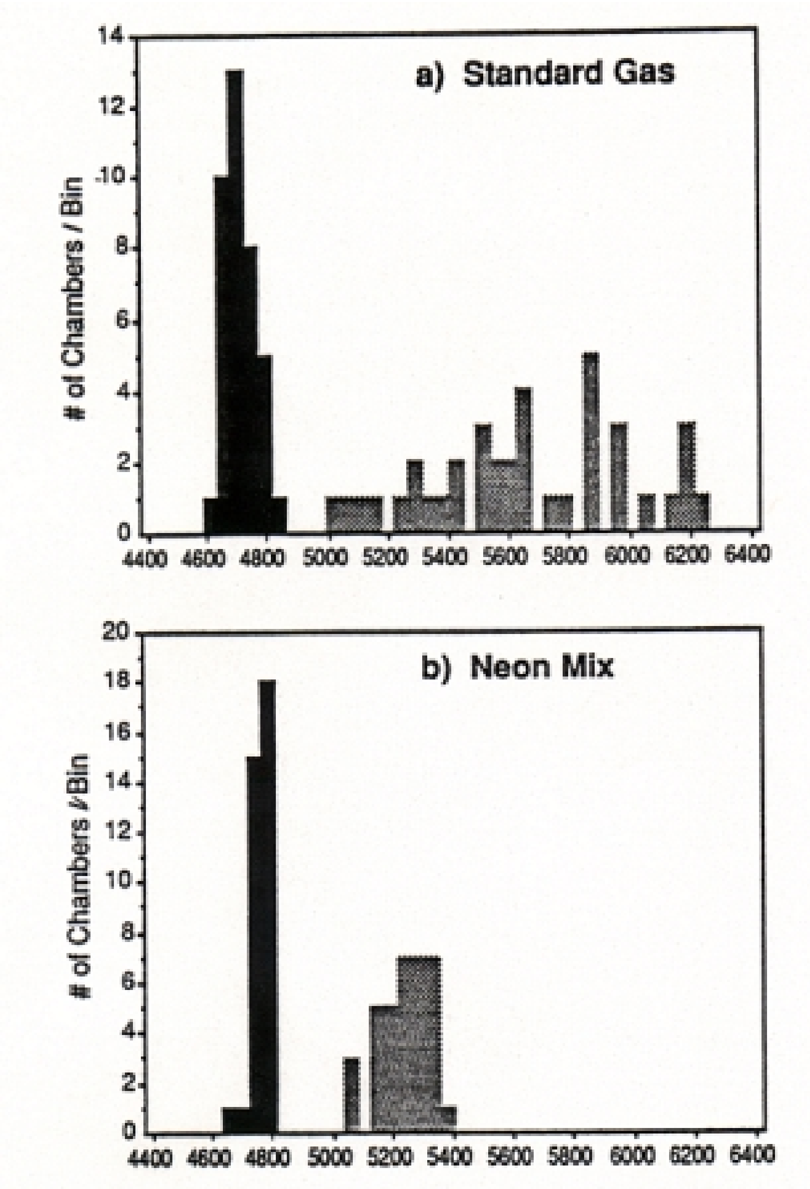
Effect of maximum burn-in voltage on plateau width

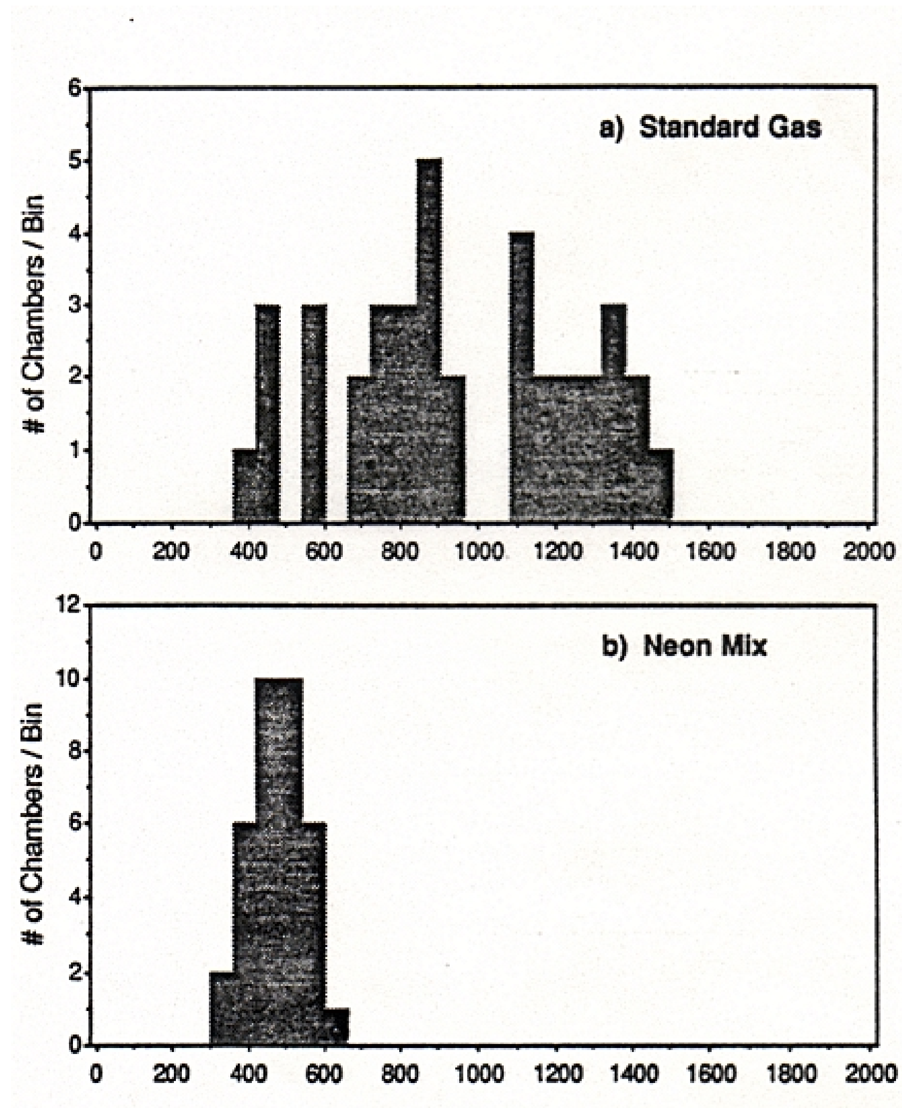
Standard Gas





Effect of gas on plateau width

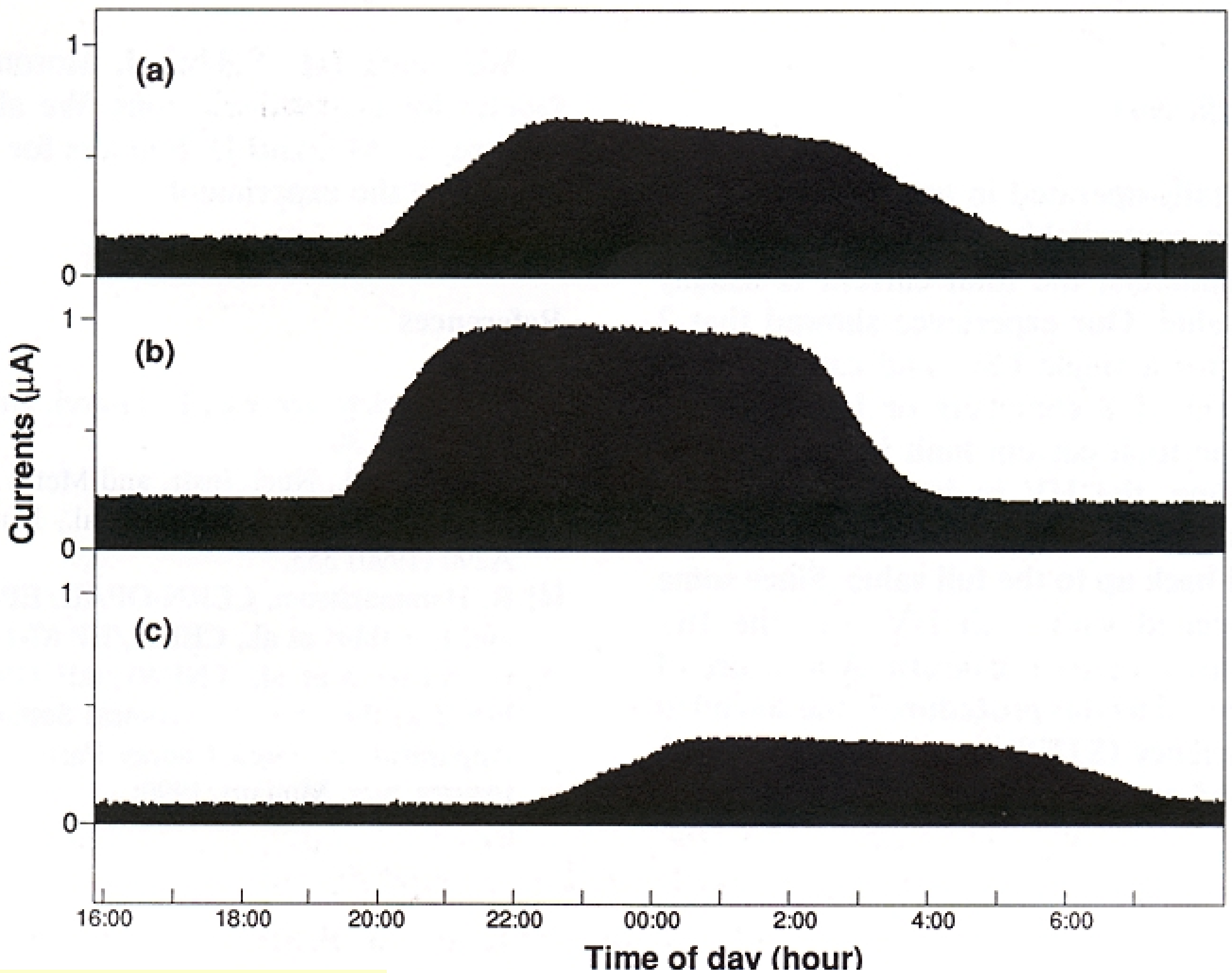




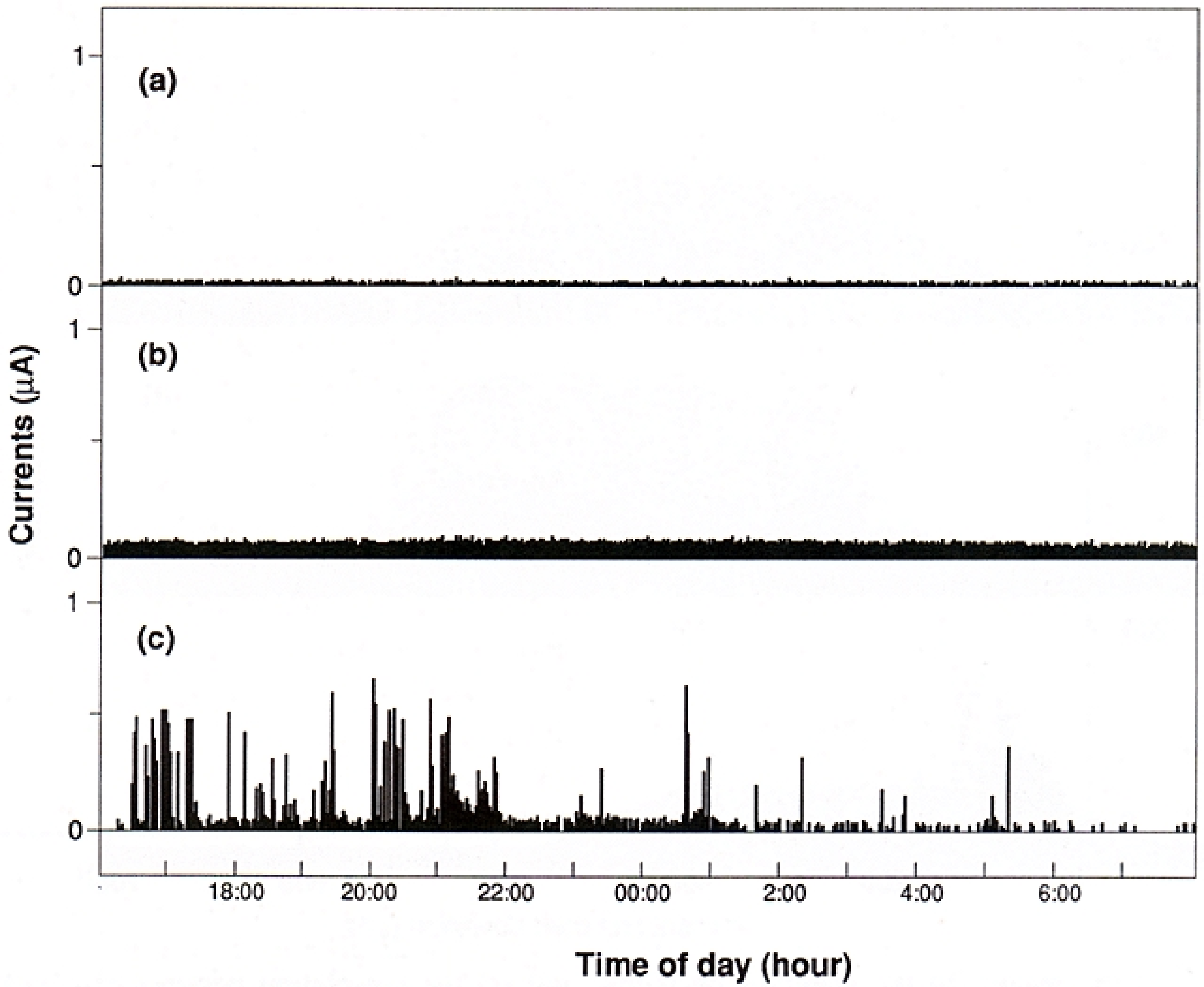
Operational experience

- Gas experience
  - Standard gas has the least amount of after-pulsing
  - LSTs work in general in other gas mixtures with less hydrocarbon (quenching power) required by safety reasons (e.g., 88/10/2 CO_2/Isobutane/neon and 88/10/2 CO_2/Isobutane/Ar)
  - Argon purity is a non-issue (99.99% purity is still cheap); 99% pure isobutane is adequate
  - LST quiescent current is susceptible to impurities in isobutane
- HV Issues
  - 40-channel CAEN SY 127 HV system is the standard
  - Need to gang chambers to save cost; time-consuming to find bad chamber in a channel
  - Chamber downtime due to “resting” could be a problem if absolute efficiency is important
  - Cheaper current monitors are available

Effect of bad gas (isobutane) on chamber current

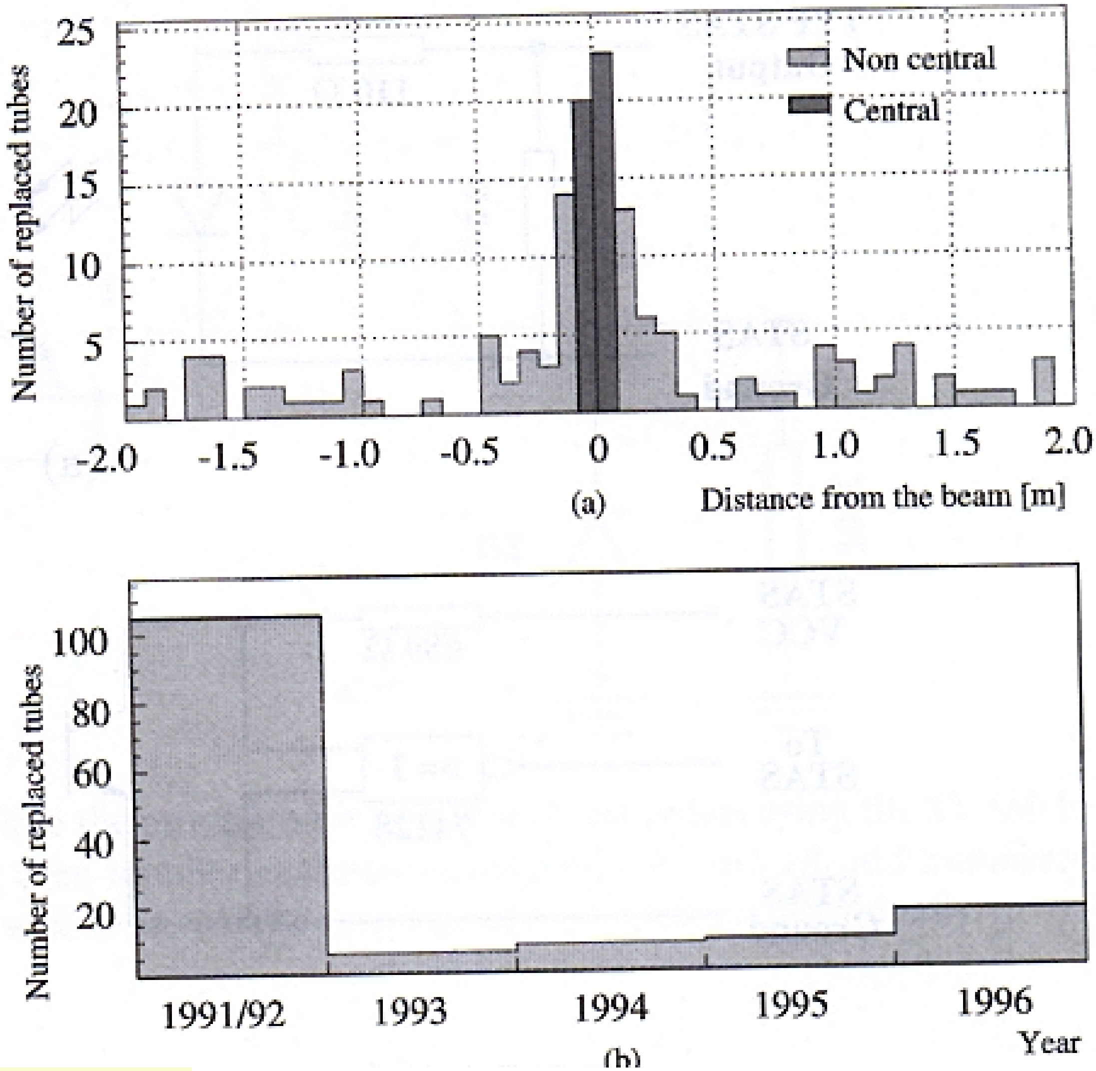


Current histories of 3 different classes of chambers



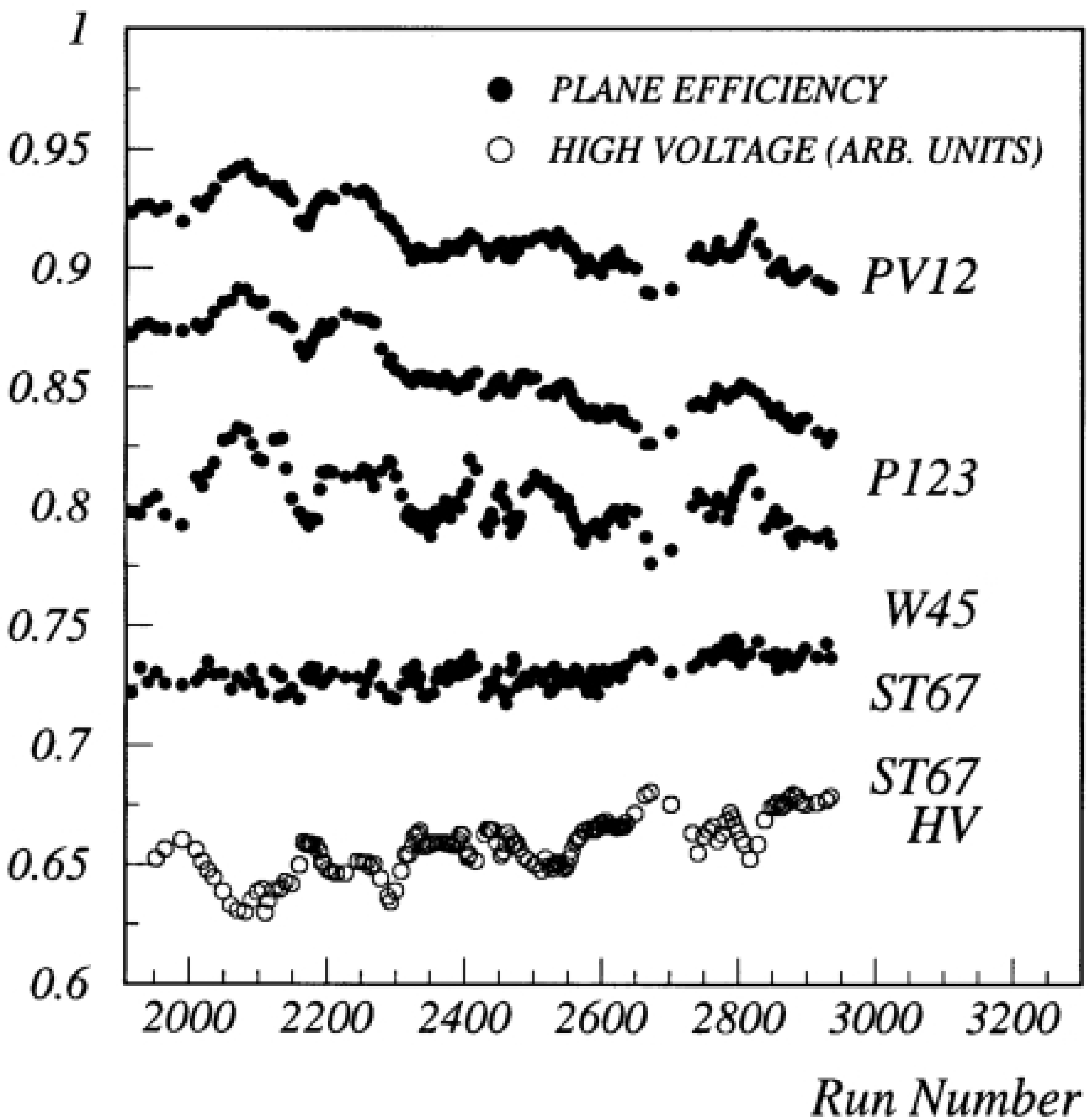
Rate limitation (SMC experience)

- About 1000 4-m SCARF-produced LSTs were deployed in SMC for muon tracking, starting from about 8 cm from beam
- LSTs close to the beam have self-sustained dark current (order 10 μA) when continuously exposed to high rates
- However, dark current does not seem to affect tracking efficiency
- Based on SMC failure rates (next slide), LSTs with resistive graphite coating can operate safely < 100 Hz
- LSTs with conductive cathode may be able to handle a higher rate
- LSTs with conductive cathode may be able to handle even higher rate if operated in the proportional mode


Number of replaced tubes
25
20
15
10
5
Non central
Central
-2.0
-1.5
-1.0
-0.5
0
0.5
1.0
1.5
2.0
(a)
Distance from the beam [m]
Number of replaced tubes
100
80
60
40
20
1991/92
1993
1994
1995
1996
Year
(b)

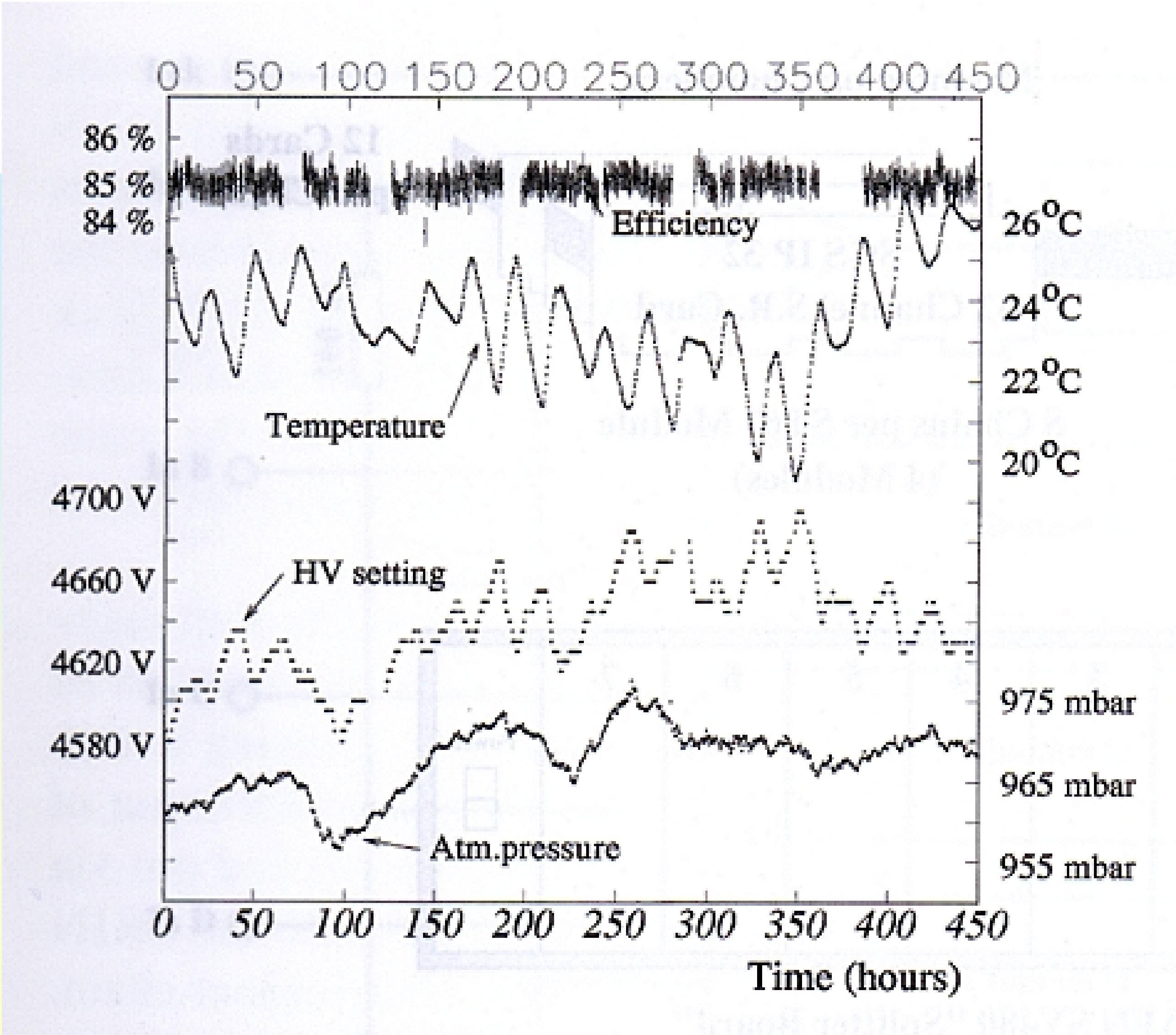
Environmental (P/T) effect

- The SMC LST system (ST67) was operated with a feedback system which uses a reference chamber to measure the gain of a LST
- The operating HV for the entire system is calculated from previous measurements
- A constant efficiency was seen at ST67 by operating the system just below the knee
- The same technique can be used to set the HV 200V above the knee for full efficiency



PLANE EFFICIENCY
HIGH VOLTAGE (ARB. UNITS)
PV12
P123
W45
ST67
ST67
HV
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
2000
2200
2400
2600
2800
3000
3200
Run Number

ST67 efficiency



Cost considerations

- The bottle-neck of the production at SCARF is the graphite coating
- The throughput is order 100 6-m chambers per shift
- The labor for the assembly at SCARF adds order \$50/chamber (0.5 m^2)
- The cost of capital equipment adds \$10/chamber for 1 shift
- Cost can be further optimized if an order of magnitude more chambers are needed.

How to further improve LSTs adiabatically?

- Reduce or use finer-grade marble filler in PVC (observation: smoother the surface, better the chamber)
- LVD-style wire support is a weak link. Need to have something more rigid. Rectangular twister?
- Increase overall mechanical rigidity

More radical ventures (R&D)

- LST with copper tapes on PVC side walls actually worked. Therefore, open profiles with thin metallic fin (high work function) on insulating platform/base will most likely work (reduce dead area and increase mechanical rigidity)
- Extruded carbon-loaded PVC profiles seem to work (KASCADE)
- Double-sided conductive profile holds good promise if one needs to
- Fine-tune cell dimensions & wire diameter (match wire diameter with cell size)
- Optimize modular size to minimize gap losses